Electromagnetic Waves

Electromagnetic Radiation

Read to Learn

What are electromagnetic waves?

Suppose you live in a remote location. Would you be able to have electric lights? Could you watch television? Thanks to the Sun, the answer is yes! You could use solar panels to capture and transform the Sun's energy into electricity.

Energy from the Sun travels in waves. Many types of waves can travel only through a medium, or matter. Waves in a pond, for example, require water to travel. Waves from the Sun are different. They can travel through empty space. *A wave that can travel through empty space and through matter is called an* **electromagnetic wave.** These waves radiate, or spread out, in all directions from a source. *Energy carried by an electromagnetic wave is called* **radiant energy.** Another name for radiant energy is electromagnetic radiation.

You will read in this lesson that the Sun is not the only source of radiant energy. However, the Sun does provide most of Earth's radiant energy. You also will read about how electromagnetic waves form, and you will learn about some properties of electromagnetic waves.

How Electromagnetic Waves Form

Electromagnetic waves form when an electric charge accelerates by speeding up, slowing down, or changing direction. They can form when a charged particle vibrates.

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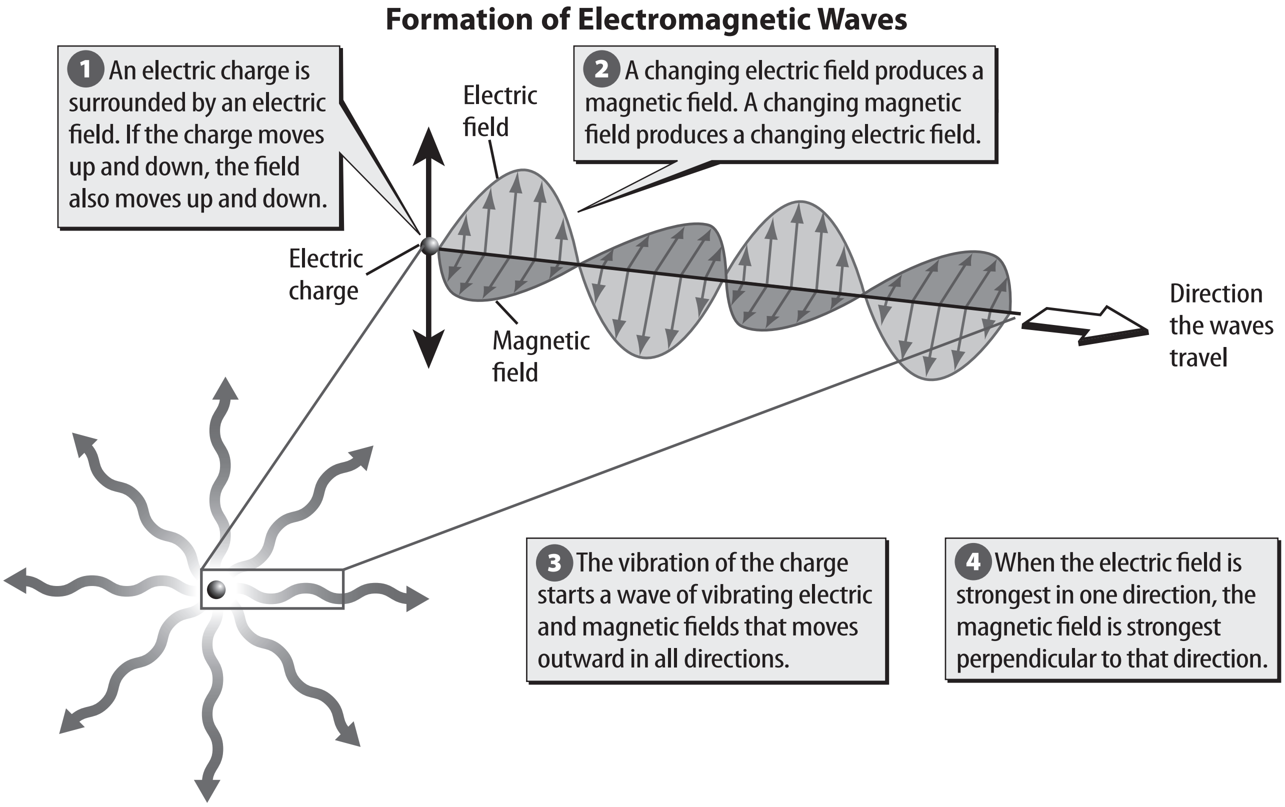

The figure above shows how the vibrating motion of an electric charge produces an electromagnetic wave. One complete cycle of vibration produces one wavelength of a wave.

Force Fields If you ever have played with a magnet, you know that it is surrounded by a field, or an area, where the force of the magnet is present. The same is true for a charged particle such as an electron. An electric field surrounds the charged particle.

Connected Fields Scientists have found that electric fields and magnetic fields are related.

- A changing (increasing or decreasing) electric field produces a magnetic field.
- A changing magnetic field produces a changing electric field.

As a charged particle vibrates, the electric field around it vibrates. This changing electric field produces a magnetic field. As the magnetic field changes, it produces a changing electric field. These connected fields spread out in all directions as electromagnetic waves. Just as shaking the end of a rope produces a wave, a vibrating charge produces a wave.

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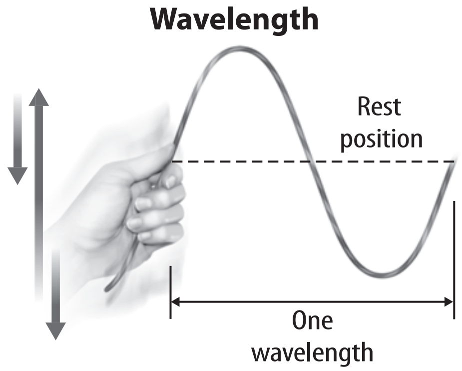
Properties of Electromagnetic Waves

Electromagnetic waves usually are drawn as a single curve, like the rope in the figure to the right. The waves are called transverse waves because the disturbance is perpendicular to the direction they travel.



Wavelength and Frequency Shaking a rope up and down one time, as shown in the figure, produces one wavelength. A charged particle also produces one wavelength when it moves up and down one time. As with all waves, the wavelength and frequency of electromagnetic waves are related. As shown by the rope example, wavelength is the distance between any one point on a wave to the nearest point just like it (crest to crest or trough to trough). Frequency is the number of wavelengths that pass by a point in a certain period of time, such as a second. As frequency decreases, wavelength increases. You will read in Lesson 2 that electromagnetic waves are grouped according to wavelength and frequency.

Wave Speed Electromagnetic waves travel through space at 300,000 km/s or the speed of light (c). A wave's speed (s) is its frequency (f) multiplied by its wavelength (λ). To find the wavelength of a wave, divide the speed of light (c) by the frequency of the wave, as shown in the Math Skills box.

What happens when electromagnetic waves move through matter? Suppose you run across a beach toward an ocean. You move quickly over the sand, but you slow down in the water. Electromagnetic waves behave similarly. When they encounter matter, electromagnetic waves slow down.

Sources of Electromagnetic Waves

When you hear the term *electromagnetic radiation* or *radiant energy*, you might imagine dangerous rays that you should avoid. It might surprise you to learn, however, that you are a source of electromagnetic waves! All matter contains charged particles that constantly vibrate. As a result, all matter—including you—produces electromagnetic waves and, therefore, radiant energy. As an object's temperature increases, its particles vibrate faster. Therefore, the object produces electromagnetic waves with greater frequency, or shorter wavelengths.

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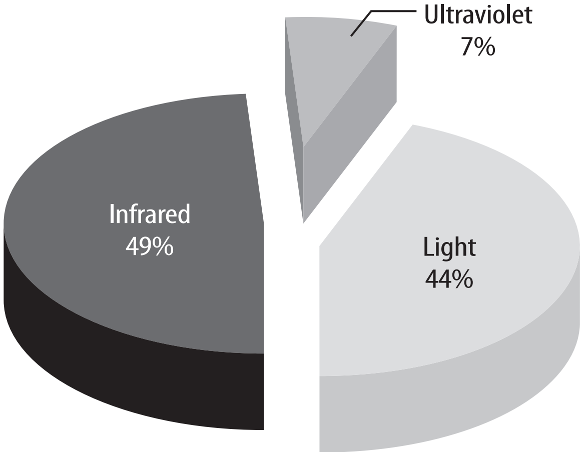
The Sun

Earth's most important energy source is the Sun. The Sun emits energy by giving off electromagnetic waves. Only a tiny amount of these waves reach Earth. Many areas of the Sun have different temperatures. These areas produce electromagnetic waves with different wavelengths.

As shown in the figure below, three types of waves—ultraviolet waves, visible light waves, and infrared waves—carry almost all of the Sun's energy. Infrared waves carry the largest portion of the Sun's energy.

Light waves are the only type of electromagnetic waves you can see. Infrared waves have wavelengths that are longer than light. Ultraviolet waves have wavelengths that are shorter than light. You will learn more about the different types of electromagnetic waves in Lesson 2.

Waves That Carry the Sun's Energy



Other Sources of Electromagnetic Waves

Even though the Sun is Earth's most important source of electromagnetic radiation, it is not the only source. All matter, both in space as well as on Earth, produces electromagnetic waves.

Sources in Space If you look up at the night sky, you see the Moon, stars, and planets. Telescopes on Earth and on satellites above Earth's atmosphere images of radiation emitted by these objects. Some of the radiation is visible, but most of it is not. Computers are used to add different colors to the radiation images. The colors show what the different wavelengths of radiation might look like if human eyes could detect them.

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Sources on Earth What do a campfire, a lightbulb, and a burner on an electric stove have in common? They are hot enough to produce electromagnetic waves that carry energy you can feel. Look around you right now. Your book, the wall, people, and everything else you see produce electromagnetic waves, too. You can detect some waves, but you can't detect others. Telescopes produce visible images of radiation from space. Also, special cameras produce visible images of invisible waves on Earth. The image produced with invisible waves would be very different from what you see with your eyes. It would show what objects look like if your eyes could detect the ultraviolet waves that objects emit.

The Energy of Electromagnetic Waves

Have you ever seen someone with a sunburn? Some of the Sun's waves have enough energy to damage skin cells. The energy of electromagnetic waves is related to their frequency. Waves that have a higher frequency, such as ultraviolet waves, have higher energy. Waves that have a lower frequency, such as light waves and infrared waves, have lower energy. Light from a flashlight can never damage skin cells because the light waves do not have enough energy.

The relationship of energy to other wave properties is different for mechanical waves and electromagnetic waves. The energy of a mechanical wave is related to its amplitude. For example, a water wave with a high amplitude has a lot of energy. The energy of electromagnetic waves is related to their frequency, not their amplitude. As the frequency of an electromagnetic wave increases, the energy of the wave increases.

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